DOCUMENT RESUME

ED 143 357 IR 005 128

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TITLE The Present and the Future in Educational Technology.
INSTITUTION Alfred P. Sloan Foundation, New York, N.Y.
PUB DATE May 77
NOTE 44p.

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS Autoinstructional Programs; Computer Assisted Instruction; Costs; *Educational Technology; Educational Television; *Foundation Programs; *Futures (of Society); *Higher Education; Instructional Innovation; Instructional Materials; Instructional Media; Instructional Technology; Self Pacing Machines; *State of the Art Reviews; Teacher Education

ABSTRACT

This paper provides a description of the present state of development in educational technology as it has been illuminated by the Sloan Foundation's Technology in Education program. Current developments are reviewed in relation to: (1) the computer, (2) television and video reproduction, (3) low technology, (4) self paced instruction, and (5) the reduction of costs through technology. A discussion of the kinds of experimental work needed in the future is provided in relation to training of the faculty and improving the quality and dissemination of materials. Appended is a list of Technology in Education grants awarded from 1971-76 in amounts over $20,000. (Author/STS)

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The Present and the Future in Educational Technology

An Occasional Paper from the Alfred P. Sloan Foundation

by James D. Koerner

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I
The Technology in Education Program

In December 1970 the Sloan Foundation established a "particular program" called Technology in Education, the purpose of which was to help college teachers test the instructional uses of new communications technologies. Three or four such particular programs are in operation at any given time by the Foundation, focussing on national problems that lend themselves to solution or major improvement over a period of five or six years. The Technology in Education program was brought to an end on schedule in December 1976, by which time the foundation had made eighty grants totaling about eight million dollars.

Because interest in educational technology is growing among colleges and universities, a review of the Foundation's experience may be of help to individuals and institutions now engaged in, or contemplating, the use of technology for instruction. The purpose of this Occasional Paper is not to evaluate the individual projects that have been supported, many of which are still in operation. Rather, it is to describe the present state of development in educational technology, as it has been illuminated by the Foundation's program, and to discuss the kinds of experimental work needed in the future. The experience of one philanthropic program of no great size or duration may seem to be a questionable base upon which to construct general propositions, but the program covered a wide and representative sample of experimental activities, and may admit of observations and conclusions that, however tentative, may prove helpful to others.

In establishing the Technology in Education program, the Foundation was acutely aware of the disappointments of the 1960's, a time when the overpromotion and underperformance of teaching machines, language laboratories, and campus television

systems produced a good deal of disenchantment among educational institutions. But the Foundation also believed that important lessons had been learned by all hands, including the so-called knowledge industry, during that period and that the time had come when a new grant-making program of even modest size might contribute to the advancement of educational technology.

Variety is apparent in the grants made over the six years of the program, as a glance at the Appendix, which lists all grants over $20,000, will indicate. Many disciplines, technologies, and methods of investigation have been supported. A few grants have had the education of the faculty as their primary goal; all have educated the faculty as the work has gone forward. Some have been limited to a single technology; most have involved more than one. Some have supported a single researcher; most have supported a number. Some have gone to small liberal arts colleges; most have gone to major universities. Some have sought to exploit the instructional potential of simple, low-cost technology; others have been based on technologies with high initial costs but with the possibility of economies of scale in the future.

About 400 teachers and scholars have been supported to one degree or another under the Technology in Education program. They have produced, or will have at the completion of the projects, about forty full courses of technology-based instruction along with many hundreds of hours of other types of teaching materials. The program may also have provided the impetus needed to continued research and development at a number of institutions.

Preliminary results from some of the projects make useful illustrations and will be mentioned at appropriate places in what follows. Mainly, investigators in these projects are trying with the help of technology to teach pretty much the same material they have taught in the past by the lecture method. Occasionally, they find that technology allows them to do new kinds of teaching; to encompass material they were unable to teach before or to enlarge the work students are able to do on their own. Frequently they find they can reach new kinds of students on campus and off through communications technologies. Sometimes they try to convert an entire curriculum or set of courses from the lecture method to one based on the use of several integrated, reinforcing technologies. But most of the time they try to use technology in a supplementary role, as an enrichment or an extension of the regular instructional

program. To the uninitiated, these uses of technology may seem pedestrian or unaggressive, but those working in the field can testify to the difficulties of learning how to use technology in even these limited ways.

Some of the projects have demonstrated that educational technology at the least has its logistical uses in shepherding flocks of students through simple material, in monitoring the progress of each, and often in generating individually tailored examinations by means of the computer. Some have demonstrated that the tedious hours spent by instructors in certain kinds of standardized, repetitive, and expensive teaching with small groups of students—instruction, for example, in how apparatus is put together in a laboratory or of how delicate and advanced equipment is used—can be saved by putting the instruction on an audiotape that frees the student to use his eyes and hands while he listens.

Or an instructor finds that he no longer has to repeat himself, at a cost in time and patience, in giving students an advance look at a given course to allow them to make an informed choice. He has only to put an introductory lecture on videotape that any interested student can see at his convenience. Teachers of remedial courses find that technology, far from reducing the human element in instruction or driving students away, allows those with academic deficiencies to work their way through their problems without pressure or embarrassment. And students in these projects often find the mnemonic uses of technology valuable, especially at examination time, in complementing printed material and jarring their memories with sound and image.

The more ambitious projects that have been supported are still some distance from completion, and not much about them can be said. They will face one critical test in the future when departmental faculties decide whether to retain entire courses based on technology or to revert to the lecture form. If faculties opt to keep and possibly expand them, that will be an important criterion of success for these courses; if they opt to abandon them, that will be disappointing but not a waste. Either way, the people involved in these experiments will have learned a great deal about the possibilities and the limitations of technology for instruction.

II

The State of the Art in Educational Technology

A prodigious amount of work is being done throughout the country in educational technology. Much of it in education, industry, and the military services has passed the development stage and represents the routine use of proven techniques and materials. Most of it is still highly experimental. It is found in all disciplines, although spread thinly in the humanities, at all grade levels, and in all kinds of institutions. In the aggregate, this activity in educational technology, which goes forward on an impressive scale, is full of promise for students at all levels of education and indeed for people of any age outside educational institutions. But it is work whose reach still greatly exceeds its grasp.

Educational technology is not a pure science, an applied science, an art, or an academic discipline. It can be called a "field" only as a term of convenience. It still lacks a central body of theory and a corpus of recognized knowledge. It still lacks well-developed techniques of investigation. It still lacks career scholars—it is not, that is, the main professional interest or specialty of most of the people working in it. The field of educational technology is simply a variegated, nationwide collection of projects frequently isolated from and unrelated to one another, a field linked tenuously to a large number of commercial vendors and a small number of financial supporters.

Of necessity, investigators conduct their experiments on the basis of little more than hunches, half-formed theories, and some empirical evidence here and there concerning the ways in which human learning takes place with the help of technology. Through trial and error, they search for techniques with which instruction can be improved, given new dimensions, extended to more people, or made cheaper by means of a variety of new electro-mechanical

devices. The "state of the art," as engineers are wont to say, might be described in educational technology as a state of infancy merging rapidly into childhood and adolescence, as a review of particular technologies might help to demonstrate.

The computer

The preeminent technology for the present and probably the future, the computer is hardly a decade old in formal instructional settings. The first IBM 1500 Instructional System was completed in July 1966 and installed at the Brentwood Elementary School in East Palo Alto where Patrick Suppes and his associates did some of the earliest work in computer-assisted instruction in arithmetic and reading. Although the 1500 system was a financial failure for the manufacturer, who overestimated the resources of school systems as well as their readiness for the computer, it was a pioneering step that led the way for many other experimenters and manufacturers.

A decade later it would be hard to describe the range of work going on with computers in colleges and universities. One can get a rough idea of this range by leafing through the printed proceedings of the conferences that have been held annually since 1970 on the use of the computer in undergraduate instruction—six large volumes of papers on experimental projects throughout the country. At one time, the number of computers on American campuses could be stated with some accuracy, but with the coming of the mini- and the microcomputer, one can no longer even estimate. No university in the country is innocent of some kind of activity in computer-based instruction. There is not, however, much unity or coherence in this welter of development work, or collaboration among investigators in different institutions; computer-based instruction is still in the let-a-thousand-flowers-bloom stage of development.

Not everyone, it is fair to say, sees a rosy future for the computer in higher education. There are those who doubt that the computer can ever be more than an expensive turner of pages (to the computer expert, such people are comparable to those who still think the earth is flat). Does it really do anything, a skeptic would ask, that cannot be done with less cost and greater convenience by paper and pencil? If it is true that a computer allows people to master a body of facts or other simple material efficiently, does it do that job better than a programmed text? If one asks a computer to print out all of its memory, is not the result a programmed text?

On the other hand, if the only real use of a computer lies at the other end of the learning scale, at which every student is enabled to follow out an advanced line of inquiry at whatever length and in whatever direction his particular or even idiosyncratic interest takes him, can the truly massive amount of programming needed to make this possible ever be developed and refined in use? Will the equally massive amounts of money required be available? Will the cost of computer-based instruction ever fall below that of conventional instruction or compete with other technologies that are coming into use? If it is true, as some experts assert, that computer-based instruction will never be important until there is a terminal for every dozen or fifteen students, with programming on a similar scale, can the computer ever become cost-effective, or will it ever be allowed to become so in a labor-intensive industry where collective bargaining and job protection are growing phenomena?

Such questions are reasonable enough, and the answer to them quite probably will be yes. At the moment it cannot be an unequivocal yes, but if one considers the many small advances of recent years in computer-based instruction and the momentum that is rapidly building in institutions around the country, the probability that the computer will realize its promise in education is very high.

Today investigators are still searching, of course, for the disciplines and topics that best lend themselves to the power and speed with which the computer can interact with a student's mental processes. Much work goes on in drill and practice, in which the computer relieves the instructor of tiresome, repetitious teaching and at the same time provides him with a detailed record of each student's strengths and weaknesses, the individual problems encountered, the progress made. Drill and practice is a part of many of the projects supported in the Technology in Education program. One project, at Beloit College, uses the computer as a kind of omnicompetent memory trainer to which the student can bring any body of facts or information he wishes to master, can program it into the computer and proceed to drill himself at whatever length is necessary. Another project, the only one below the college level supported by the Technology in Education program, is being conducted at the Spence School in New York City to demonstrate how the computer can be used for drill and practice and close monitoring in mathematics, English, and other subjects for every student in every grade.

Much work goes on in the use of the computer as a tutor and an aid in problem solving. The computer carries on a dialogue with the student, questions him and responds to questions, leads him along predetermined paths of thought, encourages him when he is logical, remonstrates with him when he is illogical, and opens up new aspects of the subject that might not otherwise have occurred to him. Mark Hopkins might do it all better, but since no institution these days can supply a human tutor at one end of the learning log and a student at the other, the search goes on for cost-effective ways to use the computer with large numbers of students at times convenient to them and with as little pedagogical compromise as possible.

Work of this kind is being done at many institutions, including the California Institute of Technology, where an interdisciplinary group of scientists, engineers, and mathematicians, with support from the Technology in Education program, is attempting to apply to undergraduate instruction advanced computer-based tutoring that was originally developed at the graduate level. Some of this work is an attempt to extend the computer a step beyond ordinary tutoring and problem solving, and to allow the student to think creatively. Briefly described, the experiment involves putting into the computer sets of data derived from actual experiments or case histories in science and engineering, programming the computer so that the student recapitulates some of the reasoning that led to the original solution, and then permitting him to speculate, on the basis of data that are always incomplete, about other possible solutions.

In some applications, the computer is clearly superior to any tutor. Just as no mathematician can begin to match the computer in the millions of rapid calculations needed to land Viking I and II on particular spots on the Martian surface, no tutor can compete with a computer in allowing the student instantaneous access to immense amounts of information and giving him the opportunity to manipulate this information in any number of ways. The computer lends itself with special effectiveness to the exploration of statistical data, and to games and simulations that permit the student to change the value of a great many variables in a given problem and to learn the consequences immediately. An entire laboratory experiment, for example, can be simulated on the computer, saving expensive laboratory space and instructor time. If the experiment goes

wrong, the laboratory apparatus does not have to be recleaned and readjusted and the problem begun anew; the computer figuratively does it all.

Experimental work in games and simulations is found widely in the science curriculum, in management education, and in economics. One experiment is being conducted at the University of Notre Dame with support under the Technology in Education program. That institution's introductory, large-enrollment course in economics is being converted from a lecture to a computer-based course. Illustrative of the simulations involved is a problem designed to impress on the student the delicate interrelationships of interest rates, taxes, the inflation rate, the unemployment rate, the money supply, the federal budget, and other elements of the economy. A lecturer or a textbook can also explain how these factors intricately interact—at least according to one theory or another!—but a computer simulation is more effective in allowing each student to manipulate these variables for himself and discover immediately how changing the value of one affects all of the others.

The line between research and instruction with the computer is breached with great frequency, to the benefit of both students and instructors. Few people question the contribution the computer makes to research in science and engineering or even in history, art, literature, or the social sciences. No one questions the fact that the range and scope of scholarly research have been greatly extended with the computer and that the researcher is now able to explore questions and solve problems he could not begin to cope with previously. The ability of researchers to do work not possible before—to develop new knowledge—carries over to the instructional program, even for undergraduates. Students on some campuses now use the computer, not for computer-assisted instruction as usually defined, but to extract from data banks information they could not secure in any other way and to explore questions they themselves devise. Such uses of the computer are fully as important as drill and practice or highly structured tutoring and simulation.

Simple computer literacy for all students is another kind of goal emerging slowly in American institutions of higher education. Dartmouth College was the first institution to offer virtually every undergraduate the opportunity to learn something about the inner workings of computers, about programming, and about the ways in which the computer so greatly extends human capabilities. Not

all students respond to this opportunity at Dartmouth, but most do and not a few become expert, creative programmers by the time they graduate. More institutions will attempt this sort of universal computer literacy as the price of equipment continues to fall. A case can surely be made that any student who graduates from college today ignorant of the computer has a serious gap in his education. Many students, possibly most, still graduate with this handicap, but institutions will have the means to remedy the situation in the future.

The computer also has many quasi-instructional uses, as in computer typesetting and editing, which promises to reduce the cost of university press publishing and to expedite the preparation of scholarly papers at the same time that it stimulates the interest of faculty members and students in computing. Some aspects of student counseling may lend themselves to computerization. Information and guidance about careers is normally provided by one counselor working with one student. Much of this information might be supplied less expensively by an interactive computer program.

The automation of university libraries is especially promising. Computer-managed bibliographic systems are coming into being that govern the ordering of new books and serials and the cataloguing of them when they arrive, that indicate where they are in the library at any given time, and that keep track of them as they are checked out. The cost of maintaining major research libraries has been increasing for at least a decade at an unsustainable rate. Whether these costs can be reduced significantly with computers has not yet been demonstrated. Costs have not been reduced so far at the few institutions, such as the University of Chicago, where large-scale projects in computerizing library operations are under way, but they may be in the future when fully comprehensive systems have been perfected.

Costs appear to have decreased somewhat among the institutional members of the Ohio College Library Center, which is actually a national consortium, with associated regional networks of college libraries, sharing a simple computerized search-and-ordering service. Cost calculations for the many institutions involved are not easy to make, but at least the productivity of the library staffs of these institutions seems to have increased.

The greatest economies in library operations and the greatest improvements in service are likely to be realized when the research

libraries of major universities are organized into regional consortia, or conceivably into a national consortium with the Library of Congress as the center. Institutions could then share a computerized bibliographic system that would decrease the great redundancy now present in the purchase and storing of specialized materials. Two grants were made under the Technology in Education program to help with the automation of research libraries and to test the feasibility of regional consortia. One went to the Research Libraries Group, a consortium of Harvard University, Yale University, Columbia University, and the New York Public Library, to help develop a computer-based bibliographic service and a search-and-lending service that will avoid overlap in the collection of certain kinds of serials and books. The other went to Stanford University to help establish a collaborative program between that institution and the University of California at Berkeley, again using a computerized bibliographic system, and providing for tl. rapid transport of people and materials between the two libraries. These consortia of research libraries represent only the first step toward the complete automation and computer-based collaboration of university libraries, and possibly of smaller libraries as well.

What is past, then, is no more than prologue in the use of computers in higher education. What has been done to date gives educators only a glimmering of what might be possible in the future. The state of the art in computer-based instruction may still be rudimentary in relation to its potential, but the speed with which this specialty has developed in little more than a decade suggests the even greater speed with which it will grow in the future.

Television and video reproduction

In the summer of 1938, E. B. White, after seeing a demonstration of a very early prototype television system, wrote with remarkable prescience in *The New Yorker*:

> I believe television is going to be the test of the modern world, and that in this new opportunity to see beyond the range of our vision we shall discover a new and unbearable disturbance of the general peace or a saving radiance in the sky. We shall stand or fall by television—of that I am quite sure.

Whether we stand or fall by television is still at issue, but it may be that commercial television, whose offenses are so widely remarked

by educators, will find some small remission of its sins when instructional television comes to maturity. The mass audiences of commerical television have been the main stimulus to the development of video systems with which educators are now experimenting. It has been the demands and opportunities of the marketplace that have been putting video technologies of great potential into the hands of educators, who need to get on as rapidly as possible with the difficult business of learning how to use them.

The word, television, which once had a single meaning, has now become an omnibus term for a variety of techniques of encoding, by means of an electron or a laser beam, a talking picture at one site and decoding it to reproduce the original at another site. Conventional or "live" television, signifying that the picture is being sent and received simultaneously, in contrast to being stored for later use, has been widely employed in closed-circuit systems in higher education for a long time. Michigan State University, Brigham Young University, and Pennsylvania State University, to name just a few, have had many years of experience with this kind of television. Now, however, video programming can be recorded, stored, and played back in so many different ways as to make instructional television a very imprecise term.

Most observers would agree that television, whatever form it has taken at a given time and place in higher education, has so far been a disappointment, but they would find it harder to agree on the reasons. Even now there is no agreement among experts—for that matter there are not many experts—about how to define and support excellence in instructional television. Some people say that the trouble in the past has been the failure of educators to use television for anything but ordinary lectures and "talking-head" instruction; others say that such a use is not to be quarreled with, that it brings education to students at remote sites at convenient times.

Some say that commercial television has created in the student's mind such high expectations that only instructional programs matching the flawless technical professionalism of network television, replete with professional actors in the role of professors, will have a chance of holding the attention of students. (They advise foundations to make a few large grants to develop such programming.) Others say that students do not respond well to expensive imitations of commercial television, that they prefer programming that may be hopelessly amateurish but is offered in a credible man-

ner by their own recognizable professors. (Foundations are then advised to support a large number of small projects that will allow different people in different fields to experiment with the television medium and test out many ideas.) Still other experienced people say that television, whether professional or amateur, is overrated as an instrument of instruction, and that it will never revolutionize education in the way that it has entertainment, merchandising, journalism, and politics.

The experience of colleges and universities with film, a much older medium, is not irrelevant to the debate about television. A great deal of programming on film has accumulated over the years, but it is still possible for a student to go through an undergraduate education without ever seeing an instructional film. When film is used these days, it is routinely transferred to videotape for portability and convenience. It would be too much to say that film is obsolescent in higher education, but its use, which has never been general in the curriculum, is declining.

The reason for these inauspicious results is not altogether clear. With film, the problem in part has been the expense and sheer inconvenience of using it. With television, the rigidities of the broadcast or live transmission schedule, giving students and teachers no option as to time and place of viewing, have been a fundamental limitation of the medium. Television as customarily used in education has been a passive, "linear" medium whose speed and direction the student could not control and with which he could not interact. Channel space has been so severely restricted that only a small part of the curriculum or student body has been affected. And television is a technology that has been extremely expensive to install and maintain, even to the extent of programming one or two channels.

Although instruction via closed-circuit television on campus has done little to date to advance the educator's understanding of the medium, several institutions are trying to reach new audiences off-campus with broadcasting that tries to exploit the special properties of television. The oldest such enterprise is Chicago's TV College, sponsored by the City Colleges of Chicago, which has offered college courses for credit for twenty years over the educational, now the public, television channel. Miami-Dade Community College in Florida and Coastline Community College in California now broadcast courses for credit to a large audience and sell tapes to

users in other parts of the country. Video programming for both pre-college and college-level use is available to any institution from two television libraries, National Instructional Television at Bloomington, Indiana, and the Great Plains Instructional Television Library at Lincoln, Nebraska. Also, video courses in great variety are available from individual institutions; a catalogue of such materials is published and kept current by Associated Western Universities, Inc., Salt Lake City.

Perhaps the most ambitious project today in instructional television is the University of Mid-America, a consortium of seven universities in five states that has recently begun to produce courses to be broadcast over public television channels and used in other ways by participating institutions. Three courses have been broadcast to date and seem to have found a sizeable audience that includes many farm wives and others whose median age is thirty-seven and who have had no previous college work. Given the funds, the University of Mid-America plans to produce no fewer than fifty television-based courses, at about $300,000 each, over the next four years. It is the only instructional television system now using professional actors, but may modify that practice on the basis of experience.

Some people working in educational technology foresee a time when television courses in abundance can be offered to home viewers over cable systems, the signal reaching the headend of the cable system by videotape or direct satellite or microwave relay. The largest experiment of this kind has been in Ohio where the Dayton-Miami Valley Consortium has tried to use the public access channels of local cable systems to offer low-income homes, not formal instruction, but self-help advice and information about family services—a different audience from that of public television or of other instructional television projects. Cable operators in the area, however, have been reluctant to use such free programming or to promote their public access channels, which are expensive to operate even when the programming is free and which may draw viewers away from revenue-producing channels. Time may alleviate such problems, but the immediate outlook for cable-based instruction going into homes is clouded.

Aside from the conventional uses of television for instruction, the state of the art in video reproduction is improving rapidly. Videotape was a major advance for instructional television, just as it was

for commercial. It adds great flexibility and convenience to video-based instruction, as can be seen on any campus where much television work goes on. Worcester Polytechnic Institute in Massachusetts, with help from the Technology in Education program, has built an inexpensive but widely used library of videotapes. This library now contains over 1,000 tapes, most of them produced with the Institute's own faculty in makeshift facilities. The tapes run from a few minutes to an hour and cover a multitude of topics drawn from, or complementary to, the curriculum. Students check out the tapes as they would a library book and view them at their convenience at any of the playback stations generously distributed around the campus. It is a simple, unpretentious system that does nothing original with the medium of television, but it demonstrates one way in which videotape technology can penetrate an entire institution.

Portable videotape recorders that can be carried and operated by one person and that yield excellent pictures in color are coming into general use on American campuses. They offer many instructional, not to say recreational, possibilities. Work with "portapak" equipment plays a part in a number of grants made under the Technology in Education program. In one project, for example, a professor of architecture finds that portapak equipment allows him to go to building sites and record new construction processes long before these processes are covered in the professional literature used by students.

Or a political science teacher finds that he can record back-of-the-scenes events at the Democratic and Republican national conventions, including scenes that demonstrate the way in which the press covers such conventions, that are not of interest to the commercial networks but are instructive for students. A professor of business administration finds that a portapak, used for interviewing managers on the job and for illustrating a production problem, adds a new element to the case method. It seems safe to predict that students themselves are going to be even more imaginative than the faculty in discovering ways in which portable television can contribute to instruction.

A special portion of the microwave band, reserved for education by the Federal Communications Commission and called the Instructional Television Fixed Service, has not been exploited by educators to anything like the degree that was expected when

these channels were set aside in 1965. Cost has been one factor limiting the use of this low-power, point-to-point service, but the main factor seems to have been a simple lack of interest or money or perhaps of information on the part of educators. Relatively few ITFS systems are in operation and most of these are run by Catholic schools or engineering schools. Several grants were made in the Technology in Education program for the development of instructional materials on ITFS systems, mainly for the continuing education of on-the-job engineers. ITFS may be bypassed in the future by cheaper and easier means of getting video instruction to remote sites. At the moment it remains an underused resource.

Interest in "slow-scan" or frozen-frame television is growing and is reflected in several grants made in the Technology in Education program. Slow-scan television is a technique that foregoes the motion of conventional television, which requires that millions of bits of information be transmitted every second to make the picture. Instead of consuming scarce channel space and requiring other expensive equipment for getting the signal into the receiver, slow-scan television is transmitted over the telephone line that is already installed in homes or institutions. It requires only a special electronic storage box between the telephone and the television receiver. Pictures are built up within the storage box every few seconds and sent at a somewhat slower rate to the receiver. With an additional piece of equipment, the user can get a permanent print of any picture that comes on the screen.

The advocates of slow-scan television are apt to say that the moving pictures of ordinary television are not only wasteful of resources but are inferior to color slides or other kinds of still pictures as a teaching-and-learning medium. The human brain, they believe, handles and retains information gained from the frozen frame better than it does from motion. They may or may not be right, but slow-scan television is now sufficiently developed to offer educators a means of reaching new kinds of students economically in homes or anywhere else with an ordinary telephone line.

Slow-scan pedagogy is also the basis of a new system of video recording and playback developed by Peter Goldmark, the well-known inventor of the long-playing record and of the technique of transmitting color television. Goldmark has developed a method of compressing thirty hours of instructional programming onto a

standard one-inch magnetic tape. The instruction can be broken up in any way desired: thirty different hour-long programs, sixty different half-hour programs, or 120 fifteen-minute programs. Sixty different students, that is, can watch sixty different half-hour programs from one tape simultaneously. Mostly they watch still pictures while listening to the audio track or referring to printed materials, but motion is also supplied when the material calls for it. Goldmark sees many applications of his system to education, particularly in community colleges and their associated remote learning centers that try to accommodate a great many students who are interested in a great many different subjects. Eventually, he plans a home-based system into which new programs will be automatically transmitted from a central station in a highly compressed fashion late at night or at other convenient times.

The videodisc is probably the most exciting of the new techniques of video reproduction. Many informed people believe that the videodisc, combined with a small free-standing computer, will be a genuinely far-reaching development in education. Videodisc technology is not at hand in education now and may not be for several more years; nor is this the place to describe the competing commercial systems under development. Suffice it to say that videodisc technology eliminates most of the barriers that have tended to hamstring instructional television in the past. The density of information that can be encoded on the videodisc—54,000 frames in one system on a half-hour disc—is so great that the storage of video information will no longer be a problem. Cost will in all probability cease to be a problem; the cost of a single videodisc will be trivial compared to a videotape. The user will have full control of the system and will no longer be bound to the linearity of ordinary television. He will be able to call up at will any one of the thousands of frames of information on the disc, or he will be able to slow the playback down, or reverse and rerun it or any part of it. When coupled with a computer, the videodisc will become a completely interactive system giving the student the advantages of both computer-based instruction and user-controlled video reproduction.

Low technology

The best-known work in educational technology is focused on the expensive, "exotic" technologies of the computer and television.

The potentialities of a whole range of inexpensive machines, which might be labeled low technology, are often overlooked by educators. In video reproduction, for example, there is a family of small machines using film loops or other kinds of video displays that educators would find as effective for many instructional purposes as the more glamorous technologies, as well as being simpler, more portable, and far less costly. Similarly, the audio-cassette could often be employed where the much more costly video-cassette is now used. Audio devices in combination with printed matter and a sequence of color slides offer the educator a simple, highly flexible instructional system that deserves to be used more widely than it is.

Some people would say the same of radio but perhaps with less confidence. Radio was used widely by American institutions in the 1920's. Today it is used widely in other countries, but no longer in the United States. Here and there an American institution will be found using radio for instruction. Purdue University, for example, makes a great deal of use of it and offers many courses for credit by this means. But such institutions are notable for their scarcity. Of the 155 licensees making up the National Public Radio system, 104 are institutions of higher education that devote most of their air time to music and non-instructional programming.

It is doubtful that radio can be used in the United States in ways similar to those of the Open University in England: to change teaching materials on short notice instead of putting the changes in print and then in the mail, or to bring to students the views of eminent people who decline to be televised, or simply for repeating a lecture, or for any purpose where voice intonation and sound add something to instruction. Anyone who has heard the excellent dramatizations of, say, Charles Dickens's novels over BBC radio, or the review of leading journals of opinion, or the poetry readings, would not be in doubt about the instructional, or at least the broadly educational, value of radio, but American educators appear to have no interest in experimenting with this low-cost, omnipresent medium.

Microfiche is a low-cost technology growing in use and often combined with other technologies such as the computer. It is an extension of microfilm technology but with much greater reduction capabilities; extreme miniaturization is possible. Stand-alone playback equipment is easily afforded by libraries or even by individuals who make frequent use of microfiche at their homes or offices.

The chief drawback of microfiche may be psychological: students are neither used to nor fond of substituting microfiche for books. They also find playback equipment inconvenient and sometimes eye-wearying. The big microfiche libraries offered by such organizations as the Encyclopaedia Britannica Company and the National Cash Register Company have been marketed with great difficulty. The Britannica's Library of American Civilization offers librarians and educators a collection of 19,000 volumes and 6,500,000 words for $20,000. Its reduction ratio is such that 1,000 pages of print can be squeezed onto one 3 x 5 plastic card, a fiche, and the whole library stored in a file drawer. National Cash Register's Library Information System contains 30,000 books on 4 x 6 "ultrafiche," each of which can accommodate 3,200 pages.

But college librarians, who badly need the space and the funds that could be saved with a wide use of microfiche collections, find little enthusiasm among students and the faculty. They find that nothing, after all, takes the place of a book that can be carried around or a shelf of books that invites one to browse; it is not easy to browse on a playback machine. As has been true of other technologies, there was a plausible case to be made, and may still be in some circumstances, for microfiche libraries, but the main line of development in fiche is likely to be for direct instruction and in combination with other kinds of machines that permit the fast retrieval of stored information.

Holography deserves greater attention from educators than it has yet received. It is a low-cost technology that could improve the quality of instructional materials anywhere that the third dimension is needed in a visual image. Perception of depth in sculpture illustrations or architecture would seem to be a significant improvement over the usual two-dimensional reproductions, or in drama or in many laboratory experiments. Most educators are still strangers to holography, but that would change if they were to discover the uses to which it can be put.

Many other devices could be added to these examples of low-cost technology: facsimile machines that will transmit a copy of anything to a remote site in a few minutes over a telephone line; electrowriters that do a similar job at even less cost; hand-held programmable calculators that not only take the place of a slide rule but can be used for the teaching of whole lessons or topics in science, mathematics, and engineering; the ordinary daily

newspaper, which is being used in a number of communities around the country for carrying courses for college credit; and the telephone, which is being used in many projects to link scattered groups and individuals to a central instructional site.

Development work with these simple, inexpensive devices has been a part of many of the projects supported under the Technology in Education program. A project at the Health Sciences Consortium, in North Carolina, may serve for illustration. Over one-third of the nation's medical schools are now members of this consortium, whose main purpose is to sponsor the preparation of self-instructional materials for use in the medical and health field. Over 1,000 of these self-instructional "packages" have been put through a carefully developed production cycle involving the preparation of materials according to a specific structure, the testing of them at a number of sites, and their revision. Packages range from those requiring only fifteen or twenty minutes of a student's time on such a topic as how a small muscle connects to the thumb, to packages that may require several days on, for example, angina pectoris.

All of the technology involved in these packages is an audio-cassette that is keyed to a sequence of color slides that in turn is keyed to a printed programmed text. The preparation, however, of this kind of integrated, self-study package is by no means as easy or inexpensive as the equipment might suggest. The job of authoring one of these packages is demanding and requires a good deal of time of highly paid members of medical faculties. Once developed, a package eventually recovers its cost as it is bought by the medical schools of the consortium or by outside organizations. The Health Sciences Consortium is still young and still perfecting its self-instructional techniques, but it is as good an illustration as might be found of the effective use of low-cost technology on a wide scale.

Self-paced instruction

Work with the technologies of instruction takes place on the basis of many assumptions about human learning that are difficult or impossible to verify, and it takes place in close relationship to other kinds of pedagogical experimentation. Everywhere that educational technology is found, its natural collaborator, self-paced instruction, is found. The audio-tutorial method of self-paced

instruction, as well as the Keller Plan (named after the psychologist, Fred K. Keller), and many variants of both methods, provide the framework for most of the instructional materials associated with educational technology. It simply happens that when instruction is undertaken with the help of machines standing between the instructor and his students, an old pedagogical theory asserts itself: many students learn many subjects most effectively when the material is broken up into small units that have a logic and coherence of their own and that can be mastered by the student at his own speed.

Self-paced instruction has nothing necessarily to do with machines. A teacher can prepare his materials in a self-paced form without recourse to anything but the printed word, and many examples of such instruction, especially in psychology, can be found. But when machines are used for teaching purposes, instructors find it natural if not essential to organize their material into free-standing units that have a beginning, a middle, and an end; that test the student's knowledge as he undertakes the work; give him regular guidance about his progress; test him again at the end; and provide the instructor with a continuous record of the work done.

Not the least virtue of self-paced instruction, so the argument goes, is its effect on the teacher. It forces him to think more rigorously about his material than he otherwise might. He must define more precisely the goals he is trying to reach, test for them more carefully, provide his students with more frequent checks on their individual progress, and measure his assumptions about what his students learn against more detailed evidence than is usually available to him in lecture courses.

Self-paced instruction, while it permeates work in educational technology, has its problems. It produces inflated grades, some critics say. Because self-paced units of study by their nature encourage the student to keep working until he has mastered the material, as measured by the examination at the end, a plenitude of A's go on the record, sometimes for mediocre but persistent students. This top-heavy grading arouses the suspicion of other faculty members and also makes comparisons difficult with student performance in lecture courses where only a mid-term and a final examination may be given.

Other criticisms are that the self-paced method is too rigid,

that it chains students to a predetermined mode and sequence of thought, that students are deprived of the pleasure and profit of browsing through books and materials associated with a lecture course, that the whole approach is complicated and time-consuming beyond the rewards, that it has never been subjected to thorough analysis and evaluation, and that it "dehumanizes" education. There is some truth in all these criticisms, though it is hard to know which weaknesses inhere in the method itself and which may derive from a particular technology being used.

There is also truth in the claims made on behalf of self-paced instruction by its adherents: it does discipline the teacher, it does produce good results with many students, and it does appeal to students who like the chance to learn at their own speed outside the competition of the classroom. Whether it can ever be more, in a mass system of higher education, than an imitation of the Socratic dialogue has yet to be determined, but for many students it does appear to be preferable to large-class instruction.

Two grants that produced contrasting results in the Technology in Education program illustrate something of the promise and limitations of self-paced instruction when combined with various technologies. One grant went to the University of California at Davis for an experiment in which an introductory, large-enrollment course in genetics was converted from a course based on lectures to one based on videotape and self-paced units of study. The performance of this class was compared with that of two other classes taking the same introductory course by the lecture method at two other campuses of the University of California. Perfect matching of the groups was not possible (it never is) but the main variables were reasonably well controlled.

On a test given at the beginning of the course to all three classes, students at the experimental Davis campus scored 50 per cent on average while those at the two control schools scored 59 per cent. But the experimental group scored an average of 82 per cent on a test at the end of the course, for a gain of 32 points, while those at the two control schools scored 70 per cent, for a gain of 11 points. Student response to the video course was favorable; faculty response was mixed. One might not wish to pronounce this experiment an unqualified success, but the gains in student achievement were substantial, and it can surely be considered a promising example of technology-based, self-paced instruction.

The other grant went to the University of Texas at Austin, where seventeen courses in engineering and other subjects were developed according to the Keller Plan. Often the only technology used was programmed printed materials, but some use was also made of computers, videotape, and audio recorders. Seven of the Keller Plan courses were paired with seven courses taught by the lecture method, and a painstaking, professional evaluation carried out. The results indicated that students in a few of the Keller Plan courses did slightly better than students in the control courses, about the same in a few, and worse in one.

This project was probably the largest and most carefully conducted of its kind to date, but it does not give an unequivocal answer, any more than does the Davis experiment, to the question of whether students learn more with the self-paced method when it is combined with technology than with the conventional method. The question is too complex to be answered by one or two experiments. The right question is probably more like this: with what kind of students, in what subjects, under what circumstances, using what kind of technology, can self-paced instruction do a better job, either in student achievement or in some other respects, than the lecture method? The answer is being vigorously pursued by investigators in biology, physics, economics, engineering, and other disciplines. Self-paced instruction, joined naturally to technology, is now taking on the dimensions of a national movement, to which the Technology in Education program has added some momentum.

The reduction of costs through technology

Any discussion of the state of the art in educational technology must address the problem of cost reduction, which merits a close examination. Cost reduction is often cited as the main objective of development work in educational technology, but has always proved elusive. It has proved elusive even in new institutions designed from the beginning to make full use of educational technology; the student-faculty ratio in such institutions is about the same as in others, as is the per-student cost. But it must be quickly added that in a great many experiments in educational technology, a careful study of costs is frustrated by the inability of the investigators to secure from their own institutions accurate figures for the cost per hour of regular instruction so that comparisons with the experimental results can be made.

Development work on new technologies of any kind, far from reducing costs, always adds to them, which is to be expected in the development stage. But in educational technology, one cannot foresee, except through the glass darkly, what cost reductions might become possible at the end of the development period. Extrapolations of the costs of technology-based instruction are just that—extrapolations that assume a great deal about the future on the basis of the past, which in educational technology is ambiguous and short.

Hence, there is a certain artificiality in the insistence by foundations and government agencies that reducing the cost of education be the primary aim of projects they support. Such a policy may waste money as well as distort development work. In some very limited experiments, and in some of the larger projects that have been heavily financed by public or private agencies for a dozen years or more, the sponsor might reasonably insist that an emphasis be given to the reduction of costs. But for most projects today, the pursuit of cost reduction by experimenters is in conflict with their other goal of trying to discover whether and how technology can be used in any effective way.

Claims for the possibilities of cost reduction abound among researchers themselves, but are usually made on futuristic assumptions that invite argument. At one institution, for example, where a project in computer-assisted instruction is being supported by the Technology in Education program, the cost per terminal hour is just under $5.00. That cost is not especially high for the use of a large computer meant primarily for research, but a paper-and-pencil exercise will indicate that if this university invested in a smaller computer with terminals dedicated solely to computer-assisted instruction, the cost could be brought down to well below $1.00 an hour.

Such arithmetic, however, is based on a great many contestable assumptions about the amount of programming that would have to be developed, how that programming could be financed, the pedagogical effectiveness of it, the number of students who would want or could be forced to participate, the number of hours that terminals would be in use each day and night, the willingness of academic departments to relinquish a number of teaching assistants (and doctoral candidates) who would no longer be needed, and about a great many other eminently debatable matters.

Thus the argument for such an institution to reduce the cost of computer-assisted instruction by several hundred percent is highly theoretical and unlikely to be put to the test in the near future.

At another institution, a project in computer-assisted instruction being supported by the Technology in Education program carries costs that are very high at $10.00 per terminal hour. But the computer in this particular setting does nothing a tutor could not do for $5.00 an hour. To bring the cost of computer-assisted instruction below that of the tutor, the institution would have to seek the benefits of economies of scale. It would have to invest in a great many terminals and either increase its on-campus computing power or shorten its phone lines to off-campus computers. But it might feel justified in making such a large investment only after the superiority of computer-assisted instruction over cheaper methods of teaching—programmed texts, for instance, or simply ordinary lectures and laboratories—had been clearly proven; and only after it became convinced that large numbers of its students would be receptive to instruction by computer.

Other types of projects supported by the Technology in Education program appear at a superficial glance to have the potential for reducing costs but in reality lack it. One project, for instance, using a combination of closed-circuit television, videotapes, tutors, and printed materials, but no lectures, would seem to have some promise for reducing costs in the long run, although the development cost of the course is difficult at the present time to separate from its probable cost once developed. The cost of teaching this large-enrollment course in the regular lecture form is about $3.00 per student hour. The cost of teaching the experimental course in the first semester, including development costs, is about $4.00, rising to $7.00 in the second semester. It would seem possible that this technology-based course, once developed, revised, and polished would become less expensive than the lecture course if it were the standard offering for the hundreds of students who take the subject each year.

But under the most optimistic projections, the savings would not be large. When one calculates the cost of tutors, the cost of maintaining the videotapes that are the heart of the course, and the cost of facilities that allow individual on-demand service to hundreds of students, the possibility of small savings might indeed be demonstrated. But to realize these savings, the university would have to

insist that a dozen members of the department involved put the small amount of time they would otherwise spend lecturing in the television course to some other productive use—namely teaching more students—or it could discharge one or two members of the department and insist that the rest make up that teaching from time saved in the television course. The university could in theory take such steps after the television course has been put through another two or three years of trials and revisions, after it has been accepted by the department as the basic course (no small matter), and after it becomes clear whether or not many hundreds of students could be persuaded or forced to accept videotape and tutors in place of professors over an entire course. It seems unlikely that the university will proceed in this fashion.

If one looks beyond the Technology in Education program at the general field, the difficulties of cost reduction remain about the same. The well-known PLATO project (Programmed Logic for Automatic Teaching Operations) at the University of Illinois may serve as an example. It is the largest project in computer-assisted instruction in the country, having cost over $25 million since 1960 (how much over is not clear; some observers estimate it as high as $50 million). Reducing the costs of instruction has been one of PLATO's main goals from the beginning. PLATO's projections of hourly costs, based on the assumption that 4,000 time-shared terminals would be in use in the matured PLATO IV system, have changed frequently over the years, the low being twenty-five to thirty cents an hour some years ago. As of September 1976, about 1,000 terminals were actually in place at Urbana and in other parts of the country, although they could not all be in use simultaneously. The cost of an individual terminal, which must be amortized by the client or factored into the hourly costs, is now $10,500, still far above the project's goal.

The cost per terminal hour of the PLATO system is difficult to calculate inasmuch as it varies with the user and his distance from the central computer, but the cost everywhere is far above the original expectations. Again, a paper-and-pencil exercise will indicate that the hourly costs could be brought down to a level close to or below that of conventional instruction, but any such estimate must be based on a great many optimistic assumptions about the educational market, the number of students using the system, the development of an enormous amount of high-quality programming, and other matters.

PLATO IV is the most advanced of the big-computer systems of instruction in the country, and nothing said here is meant in criticism of it. The system was taken over in 1976 by Control Data Corporation of Minneapolis, which has developed plans for the extensive promotion of PLATO in both industry and education, the beginning cost to users being $15.00 a terminal hour. The system may ultimately realize the cost-reduction claims made for it, although that is very doubtful. Whether it does or not, its history to date is an illustration of the ease with which cost-reduction can be "proved" on paper and the enormous difficulty with which it is achieved in practice.

All this is not to say that the reduction of costs through technology is only a will-o'-the-wisp; economies of scale are something more than chimerical. They may be realized more often with the mass enrollments and relatively limited curriculum of public schools than with colleges and universities, but possibilities do exist in higher education. A clear demonstration of cost reduction is seen, for example, in one part of a project at Dartmouth College being supported under the Technology in Education program. A computerized music synthesizer that has been developed jointly by the music and engineering faculties is now being used to teach music theory and composition to many more students than was formerly possible, but with no addition to the faculty—a significant economy. Moreover, the synthesizer appears to have commercial and academic marketing possibilities and may be a source of revenue for the college in the future.

A different sort of example is seen in a small project supported at the University of South Carolina under the Technology in Education program. The cost of offering the MBA degree to two different groups of students was analyzed and compared. One group was made up of on-campus students taking regular lecture courses for the degree; the other was made up of individuals with full-time jobs who, unable to attend an institution on a regular basis, were taking the degree over the South Carolina statewide educational television system. The cost turned out to be about the same for both groups. But the cost of the television-based degree, in contrast to the campus-based degree, could be reduced in the future with larger enrollments. In addition, the television course allowed people to earn a degree while holding a job, thus protecting them against what economists would call "foregone earnings," which are not

normally included in studies of comparative costs but which are very real to students.

In larger projects, the goal of cost reduction, when diligently pursued and carefully built into the plans, might be realized. This may be true of a project now going forward at the New York Institute of Technology with support from the Technology in Education program. That institution is in the process of converting most of the core curriculum required of undergraduates from one that is conventionally taught to one that is broken up into an extensive matrix of integrated units of study that can be covered by the student, with appropriate help from both tutors and technology, at his own pace outside the classroom. When this system is complete, and if it is well received by students, the institution may be able to reduce the faculty sufficiently to bring the cost of the core curriculum down by perhaps 30 per cent. This would be a dramatic reduction, obviously, although one that would not be easy for institutions more traditional than the New York Institute of Technology to realize.

When all the exceptions and qualifications are noted, the fact is that the goal of cost reduction through technology remains distressingly elusive, although it has been realized in a few particular and limited situations in both the Technology in Education program and in the field at large. The labor-intensive industry of education is not easily moved toward a reduction of costs even when economies can be clearly demonstrated. They cannot be clearly demonstrated in most projects today. There may be good reason for researchers and sponsoring agencies to continue to pursue the goal of cost reduction in some experiments, but insofar as the general development of the field is concerned, the primary task of investigators for some years to come ought to be that which logically comes first: trying to find out whether new communications technologies can be used effectively at any price.

III

Looking to the Future

The problems facing the further development of educational technology are neither unique nor insurmountable. In fact, the future in educational technology, seen in an appropriate perspective of time, is very bright. The experience of the Technology in Education program indicates that communications technologies are steadily infiltrating the instructional programs of colleges and universities and suggests that they will do so in the future at an accelerating pace.

The question is simply one of how long it will take for technology to become an intimate and integral part of the higher education scene. Saying that the future of educational technology is bright is like saying the future of fusion technology is bright. One feels confident that it is but has only a hazy notion of how many years must pass before the technology can come to genuine fruition. To speed the development process, certain steps, implicit in the foregoing discussion, need to be taken in higher education.

The training of the faculty

One essential step for the future is for colleges and universities to find ways of multiplying manyfold the number of faculty members experienced in and committed to development work. That is an expensive and time-consuming step, and the difficulty of taking it is suggested by the fact that not a single recognized center now exists anywhere in the country to which interested faculty members from other institutions could be sent for what might be called basic training in educational technology.

Only two grants were made under the Technology in Education program aimed directly at increasing the number of college teachers with such training, and both of these were modest in scope. One

grant went to the University of Illinois at Chicago Circle to support a new doctoral program in which work in educational technology plays a major part. The other went to Purdue University to support a number of mid-career teachers to work in the laboratory of Professor S. N. Postlethwait, the father of one of the most widely used methods of self-paced instruction, the audio-tutorial method. Assiduous but fruitless efforts were made to find other training centers, or to find institutions of requisite quality anxious to build such centers. Although some institutions now have a cadre of faculty members of some size working in educational technology, these experimenters are still apprentices themselves and are not in a position to take on trainees from other institutions.

The lack of training opportunities is not the whole of the problem. The attitudes of academic faculties toward educational technology are at least as important. Although these attitudes cover a broad range, a general lack of enthusiasm is evident enough. Whether because of genuine professional doubts, a concern for jobs, disaffection based on hearsay or perhaps on direct observation, or for other reasons, college teachers as a group seem to remain unmoved by the promise of technology in education and uninterested in experimental work. It is an attitude that may reflect what is valued in the academic profession: an interest in educational technology presupposes, after all, an interest in pedagogy, but pedagogy has traditionally taken second place to research in American universities and has been rewarded poorly in pay, promotion, and prestige.

The director of one of the projects supported under the Technology in Education program wrote the Foundation recently, making a point that would be echoed by many another experimenter:

> Do you have any idea how threatening these kind of results [preliminary data indicating the superiority of a technology-based method of instruction] are to faculty who are emotionally committed to the traditional lecture method? We may be tarred and feathered for daring to write such blasphemy! As a matter of fact, as I understand it, the budget and ad hoc committees on this campus have taken the position that the kind of teaching we have been doing in this project is not "teaching." Are you sponsoring any research on faculty attitudes toward the use of educational technology?

Custom and the natural conservatism of the faculty no doubt have their effect. But perhaps the attitude of people working in educational technology toward their uninvolved colleagues also has an effect. The attacks they sometimes make on the "inefficiencies" of the lecture method, pointing to the rigid timetable of the lecture, the passive learning situation, the inability of the lecture method to accommodate the heterogeneity of students—such criticism has a certain inefficiency of its own: it is a poor means of proselytism in a field that badly needs proselytes.

College teachers are probably no more immune to fears of technological obsolescence than people in other occupations. Justifiably or not, they may foresee the loss of jobs in the growth of educational technology. This fear is particularly acute now, when higher education is going through a painful retrenchment. The hostility of faculty members is easy to arouse when they see instructional funds being drained off by experimental work in educational technology. Media centers and technology service centers on most campuses would not yet pass the acid test of a faculty referendum: if the faculty were asked to vote to retain the center or have the funds that support it distributed among the departments, the faculty in most places would vote the latter course. That is a difficult test to impose on any new and emerging specialty, but it may be a measure of the distance that must yet be traveled in educational technology to general faculty acceptance.

Any institution interested in speeding the process of acceptance among its own faculty might look to the matter of incentives. Like most people, college teachers respond to financial and professional incentives, but they discern very few for work in educational technology. A faculty member is more likely to make money writing a conventional textbook than authoring a major computer program, and is far more likely to be promoted for writing a scholarly book for a tiny readership than for creating a technology-based curriculum for large groups of undergraduates.

Private industry learned long ago that incentive and bonus systems built around increased efficiency, cost-cutting ideas, and improved service, can pay for themselves many times over. Comparable systems in higher education are non-existent, but the possibility of creating them deserves examination. Risk capital might be put up by institutions themselves for the most promising ideas among their faculty members; teaching loads might be reduced to

give researchers the time for development work; royalties for the development of successful technology-based programs might be paid; promotions might be tied to good work in educational technology; and outright payments might be made to faculty members who develop programs that reduce costs or improve the quality of instruction with technology. Without incentives of some kind, institutions will continue to find it difficult to change faculty attitudes and increase faculty participation in development work.

Still, the situation is not static. Faculty resistance, while strong in many places, shows signs of diminishing, particularly among the younger members of the faculty. It will diminish much further when a convincing demonstration can be made to the faculty that their job can be made easier, that their work load can be reduced rather than merely changed or made more complicated, with the help of technology. That demonstration cannot yet be made, but the trend in faculty attitudes is in the right direction, and for the time being one must settle for gradualism.

Improving the quality and dissemination of materials

If means could be found in the future to permit the sustained development of the teaching materials, the "software," of educational technology, one of the principal problems of the field might be solved. It is trite but true to say that the hardware of educational technology has always outrun the software; the hardware continues to do so today. It is to this problem, in fact, that most of the grants in the Technology in Education program have been addressed. A great deal of new software has been developed in this program, but most of it represents no more than a first-try effort by the scholars involved, with all of the imperfections that first-try efforts in education normally have.

Not widely appreciated is the fact that the transformation of instructional material from the conventional format of book and blackboard to one in which the substance is conveyed to unseen students by a variety of machines is an exceedingly demanding, frustrating, and time-consuming task. Even determining the kind of topics that lend themselves best to presentation by each kind of device is a problem requiring a good deal of experimentation, and when solved may be successful with only certain kinds of students. Once developed, a software program needs, but rarely gets, an extended series of trials and tests.

The courses and materials developed under the Technology in Education program, and those developed under most other programs, should be subjected to several more years of carefully controlled testing, revising, and retesting. But such meticulous development work is extremely expensive and demanding of long-term financial commitments. Nor is money the only cause of discontinuity and inadequate development. Investigators also run out of energy and sometimes interest; they grow weary of the skepticism or criticism of their colleagues; they move and leave the project behind; and most of all, they are drawn back to their customary scholarly research and away from further expenditures of time on what are essentially problems of pedagogy.

For all these reasons, software does not get the kind of painstaking, extended development that is necessary to raising its quality. Yet raising its quality— whether it is software for computers, television, audio and slide-tape systems, teaching machines, or other devices—is central to the further development of educational technology. It remains the most important problem of the field.

One consequence of inadequately developed software is that the majority of experiments in educational technology produce very small gains, or none, in the learning that takes place. The usual finding in experiments that have had respectable controls built into them is that students learn about as well from conventional instruction as they do from any given machine or panoply of machines. The conclusions of a great many projects indicate that where any measurable improvement takes place over conventional instruction, it is small, often insignificant. Even where the gains are indisputable, there is probably some "Hawthorne effect" at work (in which a student's awareness that he is part of an experiment stimulates him to do better work than he otherwise would) as well as some "halo effect" (in which the bias of those evaluating an experiment affects the reported results).

A few of the projects supported under the Technology in Education program have shown significant gains in student achievement, as in the genetics course, mentioned earlier, at the University of California at Davis. In other projects, students have performed slightly better than regular students and in still others slightly worse. Although the results are not yet available from some of the larger projects, there is no reason to suppose they will depart from the general experience of the field.

The question frequently asked by faculty members not involved in experimental work with technology is whether the small gains in student achievement, where they exist, are worth the money spent, the controversy and disruption sometimes caused, and the amount of faculty time consumed. Each department or institution must answer such questions for itself, but one hopes that many will recognize that small-scale gains are all that can be expected at the present time and that these gains will almost certainly be improved upon as software continues to be developed and refined in the future on the basis of experience.

The transferability of software from one institution to another is a closely related problem. Educational publishers have lost a good deal of money in the past trying to disseminate and sell instructional materials based on technology, and are not anxious to assume further risks. The problem is circular: until expensively developed software can be widely shared in higher education, cost reduction will not be possible; but transferability will not improve until the quality of the material, as demonstrated in the gains students make, improves.

Frequently materials cannot be shared because the hardware of one institution is not compatible with that of the originating institution. Frequently the faculty of one institution is not aware of the existence of such material at another institution. When an instructor is aware of it and takes the trouble, which can be more than trivial, to send somewhere to get a software program on loan so as to review it, he does not find it overly difficult to conclude that the program may be well done but is not quite the way he handles that topic himself. Even if he likes what he sees, a degree of professional pride may make him reluctant to use other people's material.

Although the barriers to the extensive sharing of materials are several, the main one is clear: the first requirement for adoption of technology-based software is that there be something worth adopting; not many first-round efforts at developing software are. Software must therefore become a great deal better than most of it now is before it will have a chance of being actually used very far beyond home base. To that end, foundations and other organizations that support development work might now consider financing fewer projects for longer periods of time. Ten years is not too long to support a major project to produce materials that have been

tested, revised, retested, and again revised, and to make a clear demonstration of their effectiveness. If long-term support for large projects is not forthcoming, educational technology will continue to develop in the haphazard and redundant fashion of the past.

It will be less haphazard if the isolation of experimenters and institutions one from another could be overcome through collaboration. There are not many examples of successful consortia in higher education that would be appropriate models for educational technology, but a few do exist. The Research Libraries Group, described earlier, is one kind of model, although it is early to judge of its success. The Health Sciences Consortium, also described earlier, is another.

A third type is seen in a consortium of engineering schools recently organized with assistance from the Technology in Education program. It is called the Association for Media-Based Continuing Education for Engineers (AMCEE) and at the time of its formation in 1976 consisted of twelve schools of engineering. Before AMCEE, these schools were independently offering television-based courses at the graduate level to on-the-job engineers at their place of work but were drawing only on their separate faculties to develop and teach such courses. This was a wasteful non-system of providing for a homogeneous group of people with a real need for, and a strong interest in, advanced education, and it prevented the offering of specialized courses for which there was a demand but no expertise in the local faculty.

The obvious solution was some kind of cooperative organization that could sponsor the development of courses and other materials for use by all the schools involved, that could share development costs among the schools, and that could afford to offer highly specialized courses that might have only a few students at a given site but a substantial number throughout the consortium. AMCEE expects its membership to grow to twenty-five or more institutions in the next few years and expects to expand its offerings to laboratory technicians and other people besides engineers working in technical jobs. AMCEE uses a revolving fund from which awards are made on a competitive basis for the development of new courses, and this venture capital will be returned to the fund as new courses are bought by the members of the consortium and by other institutions. Whether a similar consortium might be appropriate in other large professional fields such as medicine, nursing,

law, management, and public school teaching is a question that should now be explored.

Other priorities in research and development

There is an immediate need for a team of researchers that, with long-term financing and sufficient staff, will prepare the educational system for the age of "no-cost" computing. That age is not far away, possibly ten years. If instructional materials and systems are not to continue to lag well behind the hardware provided so copiously by the computer industry, a strong effort should be made now to establish at least one national center for the development of computer-based instruction. The effort is needed now, not in ten years, for it may well take a decade or longer for the development work to be done.

It is difficult for the layman to appreciate the revolution that in recent years has been in the making in computers. The industry's success in the ever-greater miniaturization of integrated circuits has regularly dropped the price of computers since 1960. Intense competition among computer manufacturers, entailing very large risks but immense rewards, insures that costs will continue to drop in the future. Large-scale integration, as it is called in the trade—the technique of compacting a large number of tiny transistors and other circuit components onto a small silicon "chip"—is mainly what the revolution is about, and it has profound implications for education, as indeed it has for communications and society. On a single chip about one-quarter the size of a human finger nail, it is now possible to put 8,000 integrated-circuit components, compared to three or four components in 1960. Within the next ten years, since miniaturization tends to proceed at an exponential rate, that number is likely to leap to a million, possibly several million!

When the time comes that a million components can be put on a chip a quarter-of-an-inch square, financing computer hardware, which in the past has been a major obstacle to the development of computer-based instruction, will cease to be a problem. Computers will be so portable, and so fast and powerful, that educators will have all they can do between now and then to discover how to exploit some part of that computer potential.

Learning how to combine universal computing with other instructional technologies, such as the videodisc, is a particular challenge for the immediate future. When the storage capacity and

random access of the cheap videodisc or a comparable technology can be driven and controlled by a cheap micro-processor that itself can handle a large amount of computing but that can also be linked when necessary to a big machine, the educator will have at his disposal a more or less unlimited technology.

He will ultimately learn how to use that technology, but he would learn much faster if the necessary research and development could go forward now. Basic problems can be addressed before the hardware is in hand, such as learning the algorithms, authoring systems, and programming procedures that will be needed for the computers that are so clearly coming in the 1980s, learning how to train a large number of people for these computers, and developing and testing a wide range of instructional materials.

Also needed in the future is more careful organization and evaluation than we have had in the past in many types of experiments. Rigorous evaluation is still premature in some instances where investigators are simply trying to discover how to use technology in any promising way, but other projects using familiar technology in familiar ways deserve a better evaluation than they get. Surmise and rough estimation as to what students are learning and how it compares to regular instruction ought to give way to more systematic and recognized techniques for measuring results.

Many projects in educational technology have no control groups of students whatever; some that do have control groups fail to match them carefully with experimental groups; some that match groups carefully try to control for only one or two variables such as SAT scores or grade point averages, and education is much more complex than that. A preoccupation with psychometrics is not being suggested, but the fact is that careful documentation of results, showing how technology-based instruction compares with conventional, is going to be necessary at some point; it will have to precede the general acceptance of educational technology on American campuses.

So time must pass before technology in education can fulfill the vision of its advocates. Many more starts and many more years of development work lie ahead before anything that could be called a technology of education, much less a unified theory of knowledge and pedagogy in which technology plays an important role, might evolve. To that end, large-scale, sustained experimentation in many technologies ought to expand the educator's knowledge of

human cognition, which in turn ought to tell him how to produce better machines than in the past and better materials to go on them.

Whether all-purpose communications centers at home will become a reality in the future; whether educators will learn how to use the incredible power of the computer to provide students with unlimited instruction tailored to their individual needs; whether the microcomputer in combination with cheap videodiscs and other technologies will bring on-demand education to the fingertips of all kinds of students; whether such transmission technologies as cable, lasers, optical fibers, and direct satellite broadcast to homes, can be combined with computers and turned into networks of virtually unlimited communications power—all this may indeed be possible in the future.

How long it will take for that future to arrive is a guessing game anybody can play, and prophets are plentiful. The experience of the Technology in Education program suggests that another twenty or twenty-five years may be needed before the first leg of the journey can be completed and technology can truly suffuse the instructional programs of colleges and universities. How long the journey to that even grander future will take, when technology will provide universal and ubiquitous instruction for anyone, anywhere, anytime, is a prediction best left to mystics and other seers.

Appendix:
Grants in the Technology in Education Program

Grants over $20,000 in educational technology awarded between 1971 and 1976 are listed below, in order of declining amounts. In addition to these grants, fifty-two grants of $20,000 or less were made. For more detailed information on all grants, the Foundation's annual reports for the years 1971 through 1976 should be consulted or an inquiry made of the project directors.

Massachusetts Institute of Technology, two grants totaling $1,110,000 for a program of research and development in the use of broadband communications systems in higher education. Project directors: Myron Tribus and Roy Kaplow.

Dartmouth College, two grants totaling $923,000 for support of an Office of Instructional Services and Educational Research, for the development of a cable television system, and for experimental projects in a number of disciplines. Project director: William M. Smith.

State University of New York at Stony Brook, $490,000 for support of a project in which the College of Engineering and Applied Sciences and three collaborating junior colleges are developing a common curriculum, based on educational technology, in engineering. Project director: John G. Truxal.

California Institute of Technology, $400,000 to allow a group of mathematicians, scientists, and engineers to continue their work in human information processing and apply it to undergraduate education. Project director: G. D. McCann.

New York Institute of Technology, $375,400 to transform the core curriculum now required of its undergraduates to a system of self-paced instruction based on educational technology. Project director: Alexander Shure.

Yale University, $350,000 to help establish the Research Libraries Group, a consortium of the libraries of Harvard, Yale, Columbia, and the New York Public Library that will share a variety of computer-based and other services. Project director: James D. Skipper.

University of Texas at Austin, $340,000 to support the development of a series of self-study courses in engineering and other subjects. Project director: James E. Stice.

University of North Carolina, two grants totaling $332,000 in support of the Health Sciences Consortium and its program for the development of self-study packages in medical education. Project director: Frank B. Penta.

Harvey Mudd College, $331,000 for the development of technology-based teaching materials in science and engineering. Project director: B. Samuel Tanenbaum.

Stanford University, $300,000 in partial support of a joint project between that institution and the University of California at Berkeley in the sharing of a computerized bibliographic service for their libraries and in developing a system for transporting people and materials between the two libraries. Project director: David Weber (Director of Libraries, Stanford).

Case Western Reserve University, $295,000 for experimentation in the use of technology for remedial instruction in pre-engineering and engineering subjects. Project directors: Yoh-Han Pao and Frederick W. Phelps.

Georgia Institute of Technology, $250,000 for support of the Association for Media-Based Continuing Education for Engineers, a consortium of institutions conducting televised and other instructional programs for on-the-job engineers. Project director: Charles R. Vail.

Southern Methodist University, $250,000 to support the development of a system of self-instructional modules covering the core work of the engineering laboratory. Project director: William F. Leonard.

University of Notre Dame, $220,000 for an experiment in the use of computers and videotape for large-enrollment courses in economics and history. Project directors: Robert E. Burns and William I. Davisson.

Purdue University, $188,000 to support a mid-career internship program in self-instructional materials and educational technology. Project director: Samuel N. Postlethwait.

University of California at Davis, $165,000 to convert a large-enrollment introductory course in genetics from a lecture course to one based on television and videotape. Project director: Kathleen M. Fisher.

Spence School, $150,000 to support the further development of the Spence demonstration model for computer-assisted instruction. Project director: Dustin H. Heuston.

University of Illinois at Chicago Circle, $150,000 to support a new doctoral program in several disciplines in which work in educational technology is a major element. Project director: Richard Videbeck.

National Federation of the Blind, $100,000 for the development and testing of pre-production models of a new, computer-based system for the use of blind persons in the conversion of printed matter to synthesized speech. Project director: James Gashel.

University of Maine at Orono, $90,000 to support experimental work in combining computer-assisted instruction with the audio-tutorial method of teaching biology. Project directors: Julian F. Haynes and Douglas A. Gelinas.

Harvard University, $89,000 for experimental work in the application of instructional technology to the teaching of courses in

physics and chemistry. Project directors: Edward M. Purcell and Francis W. Westheimer.

Worcester Polytechnic Institute, $85,000 for the continued development of a videotape library of lectures and topics in science and engineering. Project director: Kenneth E. Scott.

Beloit College, $74,800 for support of a new program in computer-based instruction. Project director: Francis M. Wheeler.

Oakland University, $58,500 for the development of a technology-based pre-calculus course in mathematics. Project director: Louis B. Nachman.

Stanford University $57,500 for a planning study for a cable communications system on campus. Project director: Edwin B. Parker.

Rollins College, $35,000 for the development of a series of interdisciplinary computer-based teaching units in science and mathematics. Project director: Jack B. Critchfield.

University of Connecticut, $35,000 for support of a study involving the University of Connecticut, Yale University, and Wesleyan University in the use of television in higher education. Project director: Glenn W. Ferguson.

Fisk University, $32,000 for the planning phase of a project in computer-assisted instruction for remediation in English and mathematics. Project director: Thomas F. Potter.

University of California at Berkeley, $25,000 to support experimental work in the use of color television and other technologies in the teaching of biology to non-science majors. Project director: William A. Jensen.